COMPUTING THE COTTON CROP FROM WEATHER RECORDS AND GINNING REPORTS.

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SYNOPSIS.

The harvest of the cotton crop usually begins in extreme southern Texas about July 1. By the middle of August picking is in progress throughout the southern portion of the Gulf Coast States and during the first decade of September this work extends to the more northern districts. Owing to the slow and tedious process of picking, however, harvest is extended over a period of several months, even after the plants are all fully matured, and is not usually finished until well into the winter season.

In conformity with an act of Congress, the Bureau of the Census, Department of Commerce, issues during each harvest season 10 preliminary reports of the amount of cotton ginned to specified dates at approximately semimonthly intervals. They are based on data collected by local agents of the Bureau who canvass the ginners. These reports are considered of great value by those interested in cotton production, as they not only place in possession of all concerned reliable information as to the rapidity with which the crop is being harvested, but by reason of affording deductions as to the amount of the final output made possible by a careful comparison of current reports with those of previous years. The earliest official estimate of the amount of cotton produced is made by the Bureau of Crop Estimates, Department of Agriculture, about December 12, of each year.

While the amount of cotton ginned to a specified date or during a given ginning period has some value as a basis for forecasting the final output, the data are often misleading when the weather factor, which so largely influences the progress of harvest, is ignored.

The rapidity of harvest varies greatly from year to year, depending principally on the earliness or lateness of the crop and the weather conditions prevailing during the harvest season. The relative amounts ginned during the earlier ginning periods in different seasons depends principally on the earliness or lateness of maturity, but later in the season the rapidity of harvest is determined by the prevailing weather conditions.

The relation between the amount of cotton ginned during November and the prevailing weather of that month has been mathematically determined as a basis for forecasting the final output.

By November 1 the cotton crop has practically matured but, on the average, 37 per cent of it remains to be ginned on that date. Fifty-seven per cent of that remaining unginned on November 1 is ginned during the month of November, on the average. These latter percentages vary greatly from year to year, depending on whether November happens to be favorable or unfavorable for picking and ginning. These variations have a very close relation to the number of rainy and cloudy days during the month, which affords a basis for computing the percentages for future years when the relation is mathematically determined. This has been done for the entire cotton belt and the results are given in the accompanying tables.

The closeness of relation between the average number of rainy and cloudy days in the cotton belt and the percentage of the cotton remaining unginned on November 1 that was ginned during November, is shown by the correlation coefficient of -0.91 ± 0.03 (Table 6). This is among the highest coefficients on record where meteorological data are involved.

Ginning data for 15 years, 1905–1919, are available [1] and computations have been made for this period on the basis as outlined, with excellent results. The final computations are shown in Table 8, from which it will be noted that the average error in the computed totals for the 15-year period was only 1.5 per cent, with an error as great as 2 per cent in only 5 of the 15 years, while it was less than one-half of 1 per cent in one-third of the years. By the application of the constants of the equation, shown in Table 7, to the November weather data in future years a reliable computation of the cotton crop can be made in less than 5 minutes after the amount of cotton ginned to December 1 is reported by the Bureau of the Census. The final report of yield is not made by that Bureau until the latter part of March, or later.

The progress of harvest, or ginning, of the cotton crop each year is shown by reports issued by the Bureau of the Census, Department of Commerce. These are issued on September 1, September 25, October 18, November 1, November 14, December 1, December 13, January 1, January 16, March 21, and later an annual report showing the total production. In the MONTHLY WEATHER REVIEW for January, 1917, **45**: 6–10, the writer gave the results of a preliminary study of the relation between the weather conditions prevailing and the amount of cotton ginned during certain of these ginning periods. This showed that the variations in the amount ginned from year to year during the earlier periods of the harvest season depended, principally, on the earliness or lateness of the crop, and that this, in turn, depended largely on the temperature conditions during the early season of plant growth, mainly during May and June. In addition, it was shown that later in the harvest season the current weather conditions were closely related to the relative amounts ginned from year to year during a given period.

Several additional years of record are now available which substantiate the former conclusions in this respect. With these at hand, a more extensive study has been made of the effect of weather on the cotton harvest, with application of the weather data to the entire cotton belt; the results are given briefly herewith.

Owing to the fact that the double ginning period from November 1 to December 1 is the only one that gives ginning data for an integral calendar month early enough to be of interest from the standpoint of a crop forecast, that period has been selected for this study. Meteorological data are compiled on a monthly basis and, consequently, the selection of any other period would involve a recomputation of data for the entire cotton belt, necessitating a large amount of clerical labor.

The frequency of rainfall and the amount of cloudy weather are the most important meteorological conditions affecting picking. Owing to the nature of the open cotton and the method of handling after gathering, the progress of picking necessarily is greatly affected by the occurrence of rain and by cloudy weather which prevents the staple from drying out so that picking can be accomplished. It is not surprising, therefore, that we find a closer relation between the number of rainy and cloudy days and the amount of cotton harvested than apparently exists between the actual amount of rainfall and the cotton harvested. Light rain with cloudy weather causes delay as serious as heavy rains for the same period.

A correlation has been made between the average number of rainy and of cloudy days during November for each year, and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November. That is, for the purpose of making a forecast of the entire crop, the amount of cotton remaining to be ginned on November 1 is treated as though it were the total crop. When this amount is estimated, it becomes necessary only to add the amount ginned prior to November 1, a known quantity, for completing the computation for the entire crop. The 15-year period from 1905 to 1919, inclusive, was used in this study, the former year being the first for which ginning reports are available. In all cases the cotton data are expressed in values representing the nearest 1,000 running bales, as reported by the Bureau of the Census.

The basis on which the calculations are made is as follows: The average annual cotton production for the 15-year period, 1905–1919, was, in round numbers,

[1] Final data for 1920 had not been published when this article was completed.

12,340,000 running bales. The average number of bales ginned prior to November 1 was 7,788,000 bales, or 63 per cent of the total crop. At this time, November 1, the cotton crop has practically matured, but owing to the slow process of picking, harvest continues for several months later. The average amount remaining unginned on November 1 was 4,553,000 bales, 57 per cent of which was ginned during November, on the average. This latter percentage varied greatly from year to year, depending on whether November was favorable or unfavorable for picking and ginning. The variations show a very close relation, however, to the number of rainy and cloudy days during the month, which affords a basis for computing these percentages for future years. This relation has been mathematically determined and the resultant constants applied to the November weather for an indication of the proportion (or percentage) of the amount remaining unginned on November 1, that was ginned during that month. With a knowledge of the actual amount ginned during November and its percentage relation to the total remaining unginned on the first of that month (as computed from the November weather records), the quotient of the amount ginned divided by the computed percentage gives an indication of the actual total remaining unginned on November 1. By adding to this the amount ginned prior to November 1 the computation for the entire crop is accomplished.

Table 1 shows the average number of rainy days in November for each of the 10 cotton-belt States and for each of the 15 years of record. Table 2 shows the average number of cloudy days in like manner. In each case the averages for the entire State were used, except for Tennessee, where records for selected stations in the western portion of the State (the cotton district) were substituted for the State averages.

In view of the fact that wide variations exist in the amount of cotton harvested in the respective States, the State averages of meteorological data obviously could not logically be combined on an equal basis for the purpose of correlation with the ginning reports. For example, there is ginned, on the average, in Texas about five times as much cotton in November as is ginned in Louisiana during the same month, and to give the meteorological data in the latter State an equal weight with that in the former would clearly be improper. In view of this, ratios have been computed for the several States, based on the average amount of cotton ginned during November in each. These ratios are shown in the lower section of Table 4.

Table 3 shows the averages of the cloudy and rainy days for each State during the period under consideration, while Table 4 shows these averages weighted on the ratio basis. The last column of Table 4 contains the data used for correlation with the November cotton ginning.

Table 5 shows the amount of cotton remaining unginned on November 1 and the amount ginned during that month; also the percentages of the amount remaining unginned on November 1 of the amount ginned during that month. (The November ginning divided by the amount unginned on November 1.)

The usual preliminary procedure of preparing a dot chart to determine whether or not there is a significant relation existing between two variable quantities, and if so, the form that relation assumes, was followed in this case. The result is indicated in Fig. 1. It will be noted from an inspection of this chart that a very good straight line relation exists between these data, as the dots dispose themselves diagonally across the chart with considerable uniformity of arrangement. The relation from year to year for the several years of the series, as shown in figure 2, bears out in a striking manner the indications of the preliminary dot chart.

Table 6 shows a correlation of these data by the familiar least squares method. In this connection the fact that the correlation coefficient here shown, -0.91, with a probable error of only ± 0.03, is one of the highest of record where meteorological data are involved, although it is recognized that the number of cases is comparatively small.

The next analytical step is involved in Table 7. The dot chart, figure 1, tells us that the constants of the line of best fit to the data in hand may be determined from the equation $y = a + br$; that is, a straight line equation applies best, with only two unknown quantities. The solution of this equation, for the data given, is shown in Table 7. A detailed explanation of the equations used is contained in Prof. C. F. Marvin's "Elementary

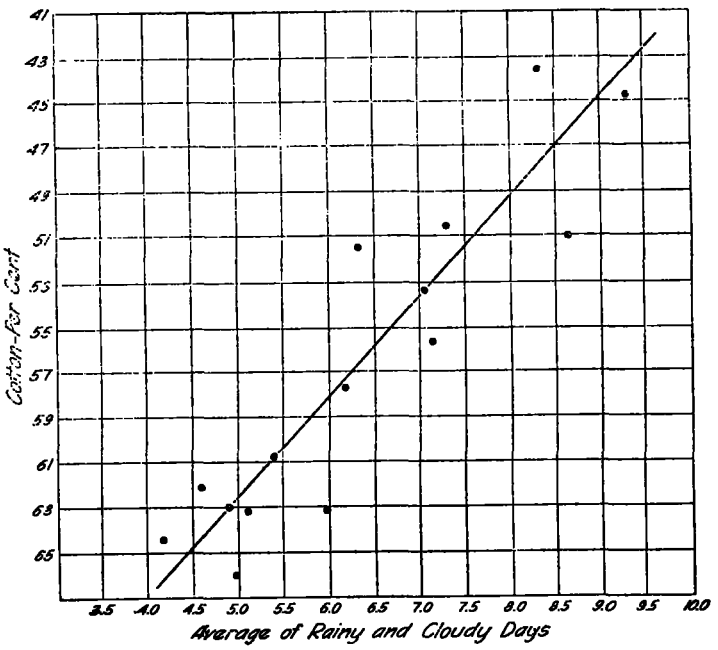

FIG. 1.—Dot chart showing the relation between the number of rainy and cloudy days in November, and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November.

Notes on Least Squares," MONTHLY WEATHER REVIEW, October, 1916, 44: 551–568, and need not be repeated here. The application of these constants to the weather data given in the column under "r" in Table 7, gives the computed percentages for the several years, shown in column 2, Table 8. The final computations are made in the last-mentioned table. Here, column 1 shows the amount of cotton ginned during November for each of the 15 years, and column 2 the computed percentages that these amounts are of the totals remaining to be ginned on November 1. The values shown in column 1 divided by those shown in column 2 give the computed totals remaining unginned on November 1, as contained in column 3. These latter values, plus the amount ginned prior to November 1 (shown in column 4), give the computations for the entire crop, shown in column 5. Column 6 gives the actual production as reported by the Bureau of the Census several months later, while column 7 shows the percentages of error in the computed forecast for the several years.

It will be noted that the computed crop from year to year is in very close agreement with the actual production, the average error for the 15-year period being only 1.5 per cent. The error is as great as two per cent in only five of the 15 years; it does not exceed 1.5 per cent in nine of the 15 years; and is less than one per cent in seven of the years. *It is less than one-half of one per cent in one-third of the years.* The relation between the computed yields and the actual yields is shown graphically in figure 3.

By the application of the constants of the equations shown in Table 7, to the November weather data and the amount of cotton ginned during that month in future years, a reliable computation can be made early in December of the total cotton crop. This total is not available through the reports of the Bureau of the Census until the latter part of March and occasionally the final report is not issued until considerably later. In addition, it will be seen that by compiling the necessary weather data and computing the constants of the equation for the double ginning period from October 18 to November 14, a similar computation could be made the latter part of November. In this case, however, special arrangements for receiving the necessary weather data, covering this period, before the November monthly summaries are available, would be necessary.

The fact that these computations are made on the basis of, and the results given in, running bales, while the final records of cotton production are expressed by the Department of Agriculture in uniform values of 500-pound bales, is inconsequential. The average weight of running bales, as reported by the Bureau of the Census during the last 10 years, varied from 502 to 508 pounds, with a mean of 505 pounds. It will be seen that by using 505 pounds as a basis, the maximum error in this connection would have been very small during these 10 years, only 3 pounds to the bale. By converting the

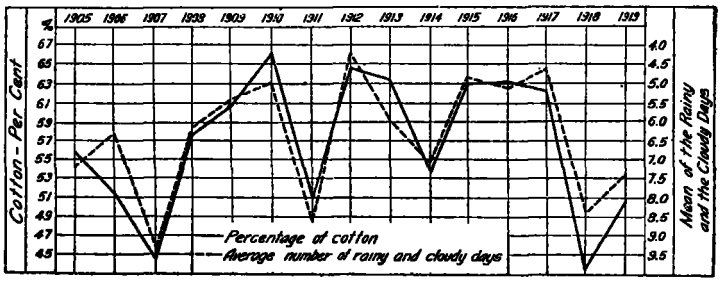

FIG. 2.—Chart showing the relation between the average number of rainy and cloudy days in November and the percentage of the cotton remaining to be ginned on November 1, that was ginned during November for each year from 1905 to 1919, inclusive.

computed running bales to uniform 500-pound bales, on the basis of 505 pounds to the running bale, the average error in the computed totals for the 10-year period from 1910 to 1919 would have been 1.7 per cent, against 1.6 per cent when expressed in running bales as shown in the tables given.

In making deductions as to the significance of the ginning reports issued by the Bureau of the Census as indications of the final output, the advantage of considering the weather factor in connection therewith can not be too strongly emphasized. The following statement appears in the last annual report of the Bureau of the Census:

"The collection of statistics of cotton ginned to specified dates was designed to place in the possession of all concerned reliable data as to the rapidity with which the cotton crop is being harvested and ginned. Statistics compiled by this method have, after a series of years, an incidental but very considerable value by reason of the deductions made possible by a careful comparison of current reports with those of previous years."

The important question in this connection is, how much better indications of the production can be had by applying the weather factor than when the ginning reports alone are considered. The records for the 15-year period, 1905 to 1919, show that on the average 84 per cent of the cotton crop was ginned prior to December 1. If these reports from year to year should furnish a reliable indication of the size of the crop, the relative amounts ginned to December 1 should be in close agreement with the

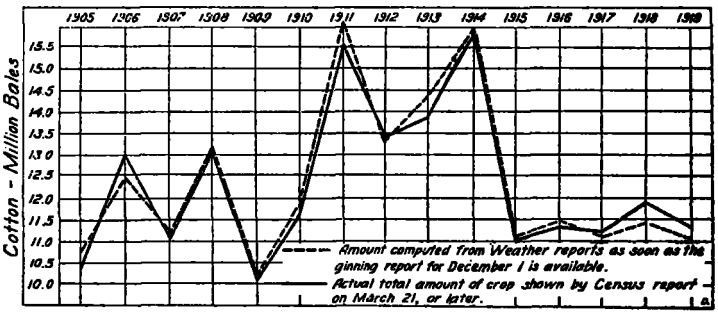

FIG. 3.—Chart showing the total cotton crop, in running bales, as reported by the Bureau of the Census on March 21 or later and the computed yield from weather conditions based on the ginning reports received on or before December 12 each year.

relative production for the respective years, for at this time only 16 per cent of the crop remains to be ginned on the average. By reducing the amounts ginned to December 1 to percentages, based on the average amount ginned to that date, and applying the ratios to the average production for computing the total crop, we find that considerable variations from the actual production frequently appear in the computed output. The errors by this method exceed half a million bales in more than half the years; the maximum error is more than 10 per cent and the average error for the 15-year period is 4.5 per cent, against an average of 1.5 per cent when the weather conditions are taken into account, as computed from the accompanying tables. It may be pointed out also that with the constants of relation between weather and ginning, as shown in Table 7, established, and the weather data for November available, the computation of the final output can be made in less than five minutes after the amount of cotton ginned to December 1 is reported by the Bureau of the Census.

The first, or preliminary, official estimate of the cotton crop is made from year to year by the Bureau of Crop Estimates about December 12. This report is based on the amount of cotton remaining to be ginned as estimated by the correspondents and agents of the Bureau distributed throughout the cotton belt. In connection with this preliminary estimate the following abstract from a note appearing in the *Weekly News Letter* of February 2, 1921, may be of interest:

"An index to the accuracy of the estimates made by the Bureau of Crop Estimates, United States Department of Agriculture, is shown by a comparison of the estimates on cotton yields made by the bureau in December with the annual report of bales ginned issued by the Bureau of the Census the following March. The deviation of the estimates from the census during the period of 20 years, 1900 to 1919, inclusive, was 2.5 per cent and the average underestimate for the 20 years 1½ per cent. In 1915 and 1916 it was less than one-half of 1 per cent—and for the last three years it was about 3 per cent under the final census report."

TABLE 1.—*Mean number of rainy days, November.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	4	3	4	6	6	7	6	5	4	6
1906	3	3	3	5	5	4	8	6	6	6
1907	10	10	11	10	8	8	10	6	4	8
1908	4	3	8	4	5	5	8	8	4	4
1909	4	3	3	3	5	5	5	7	7	5
1910	4	4	5	5	5	5	6	3	1	2
1911	9	8	8	10	8	6	11	7	4	4
1912	5	4	4	4	4	4	4	2	2	2
1913	3	2	3	3	3	3	5	5	7	6
1914	6	6	6	7	6	7	8	4	2	6
1915	5	4	4	5	6	5	9	6	2	3
1916	6	4	5	5	5	3	7	5	4	3
1917	4	4	3	3	4	2	6	4	4	2
1918	5	7	8	7	7	8	9	6	6	7
1919	5	3	5	6	8	7	10	7	6	5

TABLE 2.—*Mean number of cloudy days, November.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	8	7	8	10	11	12	9	9	5	13
1906	4	4	5	8	7	8	10	9	12	11
1907	10	11	11	11	10	11	11	9	6	11
1908	4	4	5	9	8	10	10	9	7	8
1909	4	3	3	4	5	6	8	9	10	10
1910	4	4	6	9	9	9	9	5	3	7
1911	10	13	12	11	9	11	16	8	7	10
1912	4	4	5	5	6	7	8	4	3	6
1913	4	4	5	4	6	8	13	11	12	12
1914	7	7	7	8	10	11	12	9	5	11
1915	5	4	4	6	7	6	10	9	3	4
1916	6	7	6	6	5	4	6	6	5	5
1917	7	5	5	6	7	4	11	9	6	3
1918	7	9	9	9	9	10	11	11	9	12
1919	7	6	9	9	10	9	11	10	8	9

TABLE 3.—*Mean of the cloudy and the rainy days.*

Year.	N. C.	S. C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.
1905	6.0	5.0	6.0	8.0	8.5	9.5	7.5	7.0	4.5	9.5
1906	3.5	3.5	4.0	6.5	6.0	6.0	9.0	7.5	9.0	8.5
1907	10.0	10.5	11.0	10.5	9.0	9.5	10.5	7.5	5.0	9.5
1908	4.0	3.5	6.5	6.5	6.5	7.5	9.0	8.5	5.5	6.0
1909	4.0	3.0	3.0	3.5	5.0	5.5	6.5	8.0	8.5	7.5
1910	4.0	4.0	5.5	7.0	7.0	7.0	7.5	4.0	2.0	4.5
1911	9.5	10.5	10.0	10.5	8.5	8.5	13.5	7.5	5.5	7.0
1912	4.5	4.0	4.5	4.5	5.0	5.5	6.0	3.0	2.5	4.0
1913	3.5	3.0	4.0	3.5	4.5	5.5	9.0	8.0	9.5	9.0
1914	6.5	6.5	6.5	7.5	8.0	9.0	10.0	6.5	3.5	8.5
1915	5.0	4.0	4.0	5.5	6.5	5.5	9.5	7.5	2.5	3.5
1916	6.0	5.5	5.5	5.5	5.0	3.5	6.5	5.5	4.5	4.0
1917	5.5	4.5	4.0	4.5	5.5	3.0	8.5	6.5	5.0	2.5
1918	6.0	8.0	8.5	8.0	8.0	9.0	10.0	8.5	7.5	9.5
1919	6.0	4.5	7.0	7.5	9.0	8.0	10.5	8.5	7.0	7.0

TABLE 4.—*Mean of the cloudy and the rainy days (Table 3) weighted on a scale of 100 in the ratio of the average number of bales of cotton ginned during November in each State.*

Year.	N.C.	S.C.	Ga.	Ala.	Miss.	La.	Tenn.	Ark.	Okla.	Tex.	Total.	Cotton-belt average.
1905	4.8	5.0	8.4	8.0	10.2	3.8	3.0	7.0	4.0	13.0	72.2	7.2
1906	2.8	3.5	5.2	6.5	7.2	2.4	3.6	7.5	8.1	16.2	63.0	6.3
1907	8.0	10.5	15.4	10.5	10.8	3.8	4.2	7.5	4.5	18.0	93.2	9.3
1908	3.2	3.5	9.1	6.5	7.8	3.0	3.6	8.5	5.0	11.4	61.6	6.2
1909	3.2	3.0	4.2	3.5	6.0	2.2	2.6	8.0	7.6	14.2	54.5	5.4
1910	3.2	4.0	7.7	7.0	8.4	2.8	3.0	4.0	1.8	8.6	50.5	5.0
1911	7.6	10.5	14.0	10.5	10.2	3.4	5.4	7.5	5.0	13.3	87.4	8.7
1912	3.6	4.0	6.3	4.5	6.0	2.2	2.4	3.0	2.2	7.6	41.8	4.2
1913	2.8	3.0	5.6	3.5	5.4	2.2	3.6	8.0	8.6	17.1	59.8	6.0
1914	5.2	6.5	9.1	7.5	9.6	3.6	4.0	6.5	3.2	16.2	71.4	7.1
1915	4.0	4.0	5.6	5.5	7.8	2.2	3.8	7.5	2.2	6.6	49.2	4.9
1916	4.8	5.5	7.7	5.5	6.0	1.4	2.6	5.5	4.0	7.6	50.6	5.1
1917	4.4	4.5	5.6	4.5	6.6	1.2	3.4	6.5	4.5	4.8	46.0	4.6
1918	4.8	8.0	11.9	8.0	9.6	3.6	4.0	8.5	6.8	18.0	83.2	8.3
1919	4.8	4.5	9.8	7.5	10.8	3.2	4.2	8.5	6.3	13.3	72.9	7.3
Average [1]	202	254	355	243	299	104	92	236	223	484	2,492	.....
Ratios [2]	8	10	14	10	12	4	4	10	9	19	100	.....

[1] November ginning, to nearest 1,000 bales.
[2] By States, based on average November ginning.

TABLE 5.—*Per cent of the cotton remaining unginned on November 1, that was ginned during November.*

Year.	Remaining unginned on November 1.	Ginned during November.	Per cent column 3÷2.
1	2	3	4
1905	4,037	2,232	55.3
1906	6,077	3,122	51.4
1907	4,930	2,214	44.9
1908	4,894	2,817	57.6
1909	3,055	1,859	60.9
1910	4,222	2,794	66.2
1911	5,582	2,846	51.0
1912	4,620	2,986	64.6
1913	5,153	3,258	63.2
1914	6,079	3,246	53.4
1915	3,689	2,325	63.0
1916	2,740	1,728	63.1
1917	4,063	2,529	62.2
1918	4,129	1,794	43.4
1919	5,021	2,539	50.6

NOTE.—The ginning figures are given to the nearest 1,000 bales.

TABLE 6.—*Correlation of mean number of the rainy and the cloudy days in the cotton belt, and the percentage of the cotton remaining unginned on November 1, that was ginned during November.*

Year.	Mean of rainy and cloudy days.			November ginning—Per cent.			Product of column 3 by column 6.
	Average.[1]	Departure.	Square of departure.	Per cent.[2]	Departure.	Square of departure.	
1	2	3	4	5	6	7	8
1905	7.2	+0.8	0.6	55.3	− 1.4	2.0	− 1.1
1906	6.3	−0.1	0.0	51.4	− 5.3	28.1	+ 0.5
1907	9.3	+2.9	8.4	44.9	−11.8	139.2	−34.2
1908	6.2	−0.2	0.0	57.6	+ 0.9	0.8	− 0.2
1909	5.4	−1.0	1.0	60.9	+ 4.2	17.6	− 4.2
1910	5.0	−1.4	2.0	66.2	+ 9.5	90.2	−13.3
1911	8.7	+2.3	5.3	51.0	− 5.7	32.5	−13.1
1912	4.2	−2.2	4.8	64.6	+ 7.9	62.4	−17.5
1913	6.0	−0.4	0.2	63.2	+ 6.5	42.2	− 2.6
1914	7.1	+0.7	0.5	53.4	− 3.3	10.9	− 2.3
1915	4.9	−1.5	2.2	63.0	+ 6.3	39.7	− 9.4
1916	5.1	−1.3	1.7	63.1	+ 6.4	41.0	− 8.3
1917	4.6	−1.8	3.2	62.2	+ 5.5	30.2	− 9.9
1918	8.3	+1.9	3.6	43.4	−13.3	176.9	−25.3
1919	7.3	+0.9	0.8	50.6	− 6.1	37.2	− 5.4
Sums	95.6	.....	34.3	850.8	.....	750.9	−146.3
Average	6.4	.....	.....	56.7	.....	.....	.....

$$\text{Coefficient correlation} = \frac{-146.3}{\sqrt{750.9 \times 34.3}} = \frac{-146.3}{160.5} = -0.91 \pm 0.03$$

[1] Shown in last column of Table 4.
[2] Shown in column 4, Table 5.
NOTE.—For a perfect negative relation between two variables, the correlation coefficient would be −1.00±0.00.

TABLE 7.—*Computation of the constants of the equation of the straight line of best fit to the data in Table 6, columns 2 and 5.*

Year.	r	y	r^2	ry
1905	7.2	55.3	51 8	398.2
1906	6.3	51.4	39.7	323.8
1907	9.3	44.9	86.5	417.6
1908	6.2	57.6	38.4	357.1
1909	5.4	60.9	29.2	328.9
1910	5.0	66.2	25.0	331.0
1911	8.7	51.0	75.7	443.7
1912	4 2	64.6	17.6	271.3
1913	6.0	63.2	36.0	379.2
1914	7.1	53.4	50.4	379.1
1915	4.9	63.0	24 0	308.7
1916	5.1	63.1	26.0	321.8
1917	4.6	62.2	21.2	286.1
1918	8.3	43.4	68.9	360.2
1919	7.3	50.6	53.3	369.3
Sums	95.6	850.8	643.7	5,276.0

$$y = a + br \quad \text{Equation 1.}$$

$$b = \frac{n(\Sigma ry) - (\Sigma r)(\Sigma y)}{n(\Sigma r^2) - (\Sigma r)^2} \quad \text{Equation 2.}$$

$$a = \frac{\Sigma y - b(\Sigma r)}{n} \quad \text{Equation 3.}$$

Substituting in equation 2 gives:

$$b = \frac{15(5276.0) - (95.6 \times 850.8)}{15(643.7) - (95.6)^2} = \frac{-2196.5}{516.1} = -4.26 \quad \text{Equation 4.}$$

Substituting in equation 3 gives:

$$a = \frac{850.8 - (-4.26 \times 95.6)}{15} = \frac{1258.1}{15} = 83.9 \quad \text{Equation 5.}$$

r, Mean of the average number of rainy and cloudy days in the cotton belt, Table 2, column 6.
y, Percentage of the cotton remaining unginned on November 1 that was ginned during November, Table 6, column 5.
[1] See "Elementary Notes on Least Squares," Charles F. Marvin, MO. WEATHER REVIEW, October, 1916, 44: 551-556.

TABLE 8.—*Computations of total cotton production by the application of the constants of the equation of the straight line of best fit, shown in Table 7, to the weather data and ginning reports for November. Cotton data given to nearest 1,000 running bales, as reported by the Bureau of the Census, Department of Commerce.*

Year.	1	2	3	4	5	6	7
1905	2,232	53.2	4,195	6,458	10,653	10,495	+1.5
1906	3,122	57.1	5,468	6,906	12,374	12,983	−4.7
1907	2,214	44.3	4,998	6,129	11,127	11,058	+0.6
1908	2,817	57.5	4,899	8,192	13,091	13,086	±0.0
1909	1,859	60.9	3,053	7,018	10,071	10,073	±0.0
1910	2,794	62.6	4,463	7,346	11,809	11,568	+2.1
1911	2,846	46.8	6,081	9,971	16,052	15,553	+3.2
1912	2,936	66.0	4,524	8,869	13,393	13,489	−0.7
1913	3,258	58.3	5,588	8,830	14,418	13,983	+3.1
1914	3,246	53.7	6,045	9,827	15,872	15,906	+0.2
1915	2,325	63.0	3,690	7,379	11,069	11,068	±0.0
1916	1,728	62.2	2,778	8,624	11,402	11,364	+0.3
1917	2,529	64.3	3,933	7,185	11,118	11,248	−1.2
1918	1,794	48.5	3,699	7,777	11,474	11,906	−3.6
1919	2,539	52.8	4,809	6,305	11,114	11,326	−1.9
Average							1.5

Column 1.—Amount of cotton ginned during November.
Column 2.—Computed percentage of the cotton remaining to be ginned on November 1, that was ginned during November (computed from equations in Table 7, applied to weather data).
Column 3.—Computed amount remaining unginned on November 1 (column 1 divided by column 2).
Column 4.—Amount ginned prior to November 1.
Column 5.—Computed total crop (column 3, plus column 4).
Column 6.—Total crop, as reported by the Bureau of the Census, Department of Commerce.
Column 7.—Percentage of error in computed amount.
NOTE.—These computations can be made as soon as the ginning report for December 1 is available, while the actual totals are not available through the report of the Census Bureau until the latter part of the following March, or later.

FORECASTING THE CROPS FROM THE WEATHER.[1]

[Abstract of presidential address of R. H. Hooker, before Royal Meteorological Society.][2]

Mr. Hooker remarked that forecasts of the harvest fell into two main groups, viz, those which predicted the recurrence of good and bad crops in cycles, and those which computed the actual amount by which the yield was improved or damaged by the weather during or shortly before the growing period. He outlined the evolution of the methods of ascertaining relationships between the weather at different seasons of the year and the subsequent harvest. Originally writers such as Gilbert and Lawes could only examine the meteorological conditions in years of exceptional abundance or scarcity. A great advance was made when Sir Rawson Rawson and, later, Sir Napier Shaw, from the study of an entire sequence of crops and previous weather conditions, suggested formulæ from which the crop might be calculated, while still wider possibilities were opened by the methods of correlation. Mr. Hooker emphasized the necessity of taking the past weather into account in predicting the harvest, as it was abundantly clear, from comparison with actual forecasts in India and elsewhere, that the weather was responsible for developments in the plant which were not visible to an observer surveying the young crops in the fields; and, although much work still remained to be done, the time was ripe for using statistics to confirm or modify the results of direct observation of the growing plants.

[1] *Quar. Jour. Roy. Met'l. Soc.*, Apr., 1921, 47:75–99.
[2] Reprinted from *Nature* (London), Jan. 27, 1921, p. 714.

BIOCLIMATIC ZONES DETERMINED BY METEOROLOGICAL DATA.[1]

551.586

By ANDREW D. HOPKINS.

[U. S. Department of Agriculture, Washington, D. C., Apr., 1921.]

In a comprehensive study of the relation of the Bioclimatic Law to the natural and artificial distribution of terrestrial plants and animals of the world the writer has developed a system of bioclimatic zones on the theory that a definite relation prevails between the range and limits of similar or equal zones of life and climate and the unit constants of *time*, *distance*, and *the thermal mean* of this law.

While the study of this relation and the development of systems of tables of constants, charts, etc., is yet in the preliminary stage, the fundamental idea of applying the law to the study of life zones, as suggested in SUPPLEMENT 9 of the MONTHLY WEATHER REVIEW, 1918, p. 38, has been developed, and tested, to a sufficient extent to warrant the presentation of the result relating to a *thermal mean principle* of forecasting the bioclimatic zones that are represented by the meteorological stations of the world.

The term *Bioclimatic Zone* has been adopted to include the elements of both life and climate that characterize the zonal complex of responses, primarily to the solar factor, and secondarily to those represented by the variable features of the earth's surface.

The classification of zones to meet the requirements of universal application is briefly as follows:

The major zones are the frigid, temperate, and tropical, designated by Roman numerals I, II, and III. These majors are divided into minor frigid, minor temperate, and minor tropical, which are designated by Arabic numerals.

I. The Major Frigid Zone is Arctic, Antarctic, and Alpine, with Minor Frigid 1, 2, 3, and 4 from the poles and from higher to lower altitudes.

II. The Major Temperate Zone is south and north of and below Major Frigid I, with Minor Temperate 1, 2, 3, 4, 5, 6, and 7, south and north of and below Minor Frigid 4.

III. The Major Tropical Zone is south and north of and below Major Temperate II, with Minor Tropical 1, 2, 3, 4, south and north of and below Minor Temperate 7.

This system of designations and classification of the zones is with the idea of adopting a terminology that is applicable to any continental or insular area of both hemispheres, instead of the usual names based on geographical features, political divisions, regions, etc., of one country or continent.

The major zones of this classification are not different from those which have long been recognized, except that their poleward and equatorward limits *do not follow the parallels of latitude even at sea level.*

The minor zones correspond in general to the minor temperate zones proposed by Dr. Merriam for North America, but his Hudsonian and Canadian do not apply to other continents and Austral and Sonoran for North America do not apply in the same way to South America or Africa.

CHARACTERIZATION OF BIOCLIMATIC ZONES.

Each major and minor zone is characterized by some peculiar element or group of elements of life and climate by which it may be recognized anywhere on the face of the earth where it is represented by greater or less land areas.

The index or characterization elements of the minor zones and their subdivisions into sections are many and varied. Some of the principal ones are the thermal

[1] Presented before the American Meteorological Society, Washington, D. C., Apr. 20, 1921.